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THE RELATIONSHIP BETWEEN GASOLINE OCTANE NUMBER AND FUEL CONSUMPTION FOR THE 1981 LIGHT-DUTY VEHICLE FLEET IN THE UNITED STATES

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OIL, GAS AND ENERGY DIVISION
INDUSTRIAL PROGRAMS BRANCH
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DAVIS ENGINEERING LIMITED
CONSULTING ENGINEERS
OTTAWA, ONTARIO

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1.0 INTRODUCTION

In a survey conducted by the Coordinating Research Council Inc. (CRC) (1), the maximum octane number requirements* were obtained for a sample of 1981-model vehicles in the U.S.

The purpose of this study is to utilize these data (in conjunction with fuel consumption estimates for the same vehicles) to obtain a relationship between the maximum octane number requirements and the percentage of the total fuel consumed by the 1981 fleet of light-duty vehicles in the U.S.

2.0 SOURCES OF DATA

Data from the following sources were utilized in the analysis.

2.1 The Coordinating Research Council Inc., Octane Number Requirement Survey Data from 1981 (1).

These data included the maximum octane number requirement of a sample of vehicles consisting of 300 cars and 18 trucks manufactured in the United States, and 92 imported cars and 7 imported trucks, for a total of 417 vehicles. The sample of vehicles had accumulated an average mileage of 10,601 miles with a range of 4,200 to 35,000 miles. The evaluations were performed using trained raters. Three different types of test fuel were

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* The maximum octane number requirement (expressed as Research Octane Number) is defined as the highest octane number fuel producing borderline knock which is induced by spark or surface ignition. This requirement is also defined as the minimum octane level for vehicle satisfaction.

evaluated; primary reference (PR) fuels, average sensitivity full boiling range (FBRU) unleaded reference fuels with sensitivities similar to those of normal commercial gasoline, and high sensitivity full boiling range unleaded (FBRSU) reference fuels with sensitivities higher than the FBRU fuels. Data obtained with FBRU reference fuels were used for the analyses in the present report.

2.2 The 1981 E.P.A. Fuel Economy Estimates for U.S. Federal (2) and California (3) Vehicles.

These data give fuel economy estimates for vehicles sold in the United States; they are given in miles per U.S. gallon and represent the results of the EPA city-cycle test. The data in the estimates identify engine size, transmission type and fuel system type for each vehicle.

2.3 Transport Canada Fuel Consumption Guide 1981 (4).

These data give fuel consumption ratings for passenger vehicles sold in Canada. The city-cycle data from this guide were used for eight vehicles evaluated for CRC for which no fuel economy figures were available in the EPA Fuel Economy Estimates.

2.4 Coordinating Research Council Inc., Vehicle Code Number to Vehicle Model Correlation.

In order to maintain confidentiality with the vehicle manufacturers, the CRC data gave code numbers in place of vehicle models. However, the vehicle code number to vehicle model correlation was obtained in confidence from the Coordinating Research Council and was used to match the fuel economy data to the Coordinating Research Council maximum octane number requirement data.

3.0 DATA CORRELATION AND REDUCTION

The data correlation and reduction sequence to determine the relationship between octane number and vehicle fuel consumption for 1981-model light-duty vehicles in the United States is outlined in the following. Each vehicle tested for the CRC was treated as a unit and no sales-volume weighting-factors were applied. By comparison sales volume weighting was applied by the CRC in the presentation of their data.

The fuel economy rating for each specific vehicle model tested for the CRC was obtained from either the Federal or California Fuel Economy Estimates and was tabulated with the maximum octane number requirement data. These fuel economy data and the fuel consumption data (Transport Canada) were determined using the EPA city-cycle test.

All of the U.S. fuel economy figures were then converted to fuel consumption figures using the following equation;

$$\text{Fuel consumption (L/100 km)} = \frac{235.2}{\text{Fuel Economy (Miles/US gallon)}}$$

The data from two of the vehicles tested for the CRC were not used because the vehicle models could not be determined. One of these was an imported car, and the other an imported truck. The sample of vehicles analysed therefore consisted of 415 vehicles.

The number of vehicles and fuel consumed were then calculated for each octane number given in the CRC data for both U.S. manufactured vehicles and for all of the vehicles (i.e. U.S. manufactured plus imported vehicles). The fuel consumed for each octane number was calculated by summing each individual fuel consumption value given for that particular octane number. For the purposes of this analysis, it was assumed that each vehicle travelled an equal distance.

Using data on the maximum octane number requirement, number of vehicles, and fuel consumption, the following calculations were performed for the Research Octane Number (R.O.N.) as well as the sum of the Research Octane Number plus Motor Octane Number divided by 2 [(R + M)/2 Octane Number].

i) For each octane number given in the CRC data, the percentage of fuel consumed (for the vehicles satisfied) was calculated. This was done by multiplying the mean fuel consumption rating for vehicles experiencing that maximum octane number requirement by the number of vehicles experiencing that maximum octane number requirement, dividing by the sum of the above products for all octane numbers represented, and multiplying by 100. This was performed for vehicles manufactured in the U.S. and for all of the vehicles.

ii) The percentage of vehicles satisfied (cumulative) was calculated for all vehicles for each octane number. The method described in the CRC report (1) was used, where the percentage of all vehicles satisfied at each octane level represents the summation of all vehicles before that level plus one half the sum at that level.

iii) The cumulative percent fuel consumed (for the vehicles satisfied) was calculated for all vehicles for each octane number. These calculations were done in the same manner as was the percent of vehicles satisfied, in that the percentage of fuel consumed represents the summation of all fuel consumed before the octane number level plus one half the sum at that level.

4.0 RESULTS

Table 1 gives the number of vehicles tested, and the percentage of fuel consumed, versus maximum R.O.N. and (R + M)/2 Octane Number requirements for the sample of U.S. manufactured vehicles and the total sample which included imported vehicles. These data are also displayed graphically in Figures 1 to 4. From these data it may be observed that although there is a broad range of maximum octane number requirements for the vehicles sampled, the majority of vehicles tested had maximum octane number requirements in the centre of the range, namely from a R.O.N. of 86 to 94 or (R + M)/2 Octane Number of 83 to 90. There was a relatively even distribution in this range for both U.S. manufactured vehicles and the total number of vehicles. The histograms displaying percent fuel consumed versus maximum octane number requirements (Figures 3 and 4) show a similar trend.

Table 2 gives the maximum R.O.N. and (R + M)/2 Octane Number requirements versus cumulative percentage of vehicles satisfied and cumulative percentage of fuel consumed, for all of the sample vehicles.

The maximum R.O.N. and (R + M)/2 Octane Number requirements versus cumulative percent satisfied are plotted in Figures 5 and 6, respectively and are compared to the curve which was generated by the CRC using sales-weighted data. The curves presented in this study show a very close correlation with the sales-weighted curves for percent satisfied vehicles given by the CRC.

The maximum R.O.N. and (R + M)/2 Octane Number requirements versus cumulative percentage of vehicles satisfied and cumulative percentage of fuel consumed are plotted in Figures 7 and 8, respectively. From these plots it can be seen that there is no appreciable shift from the percent satisfied curve when fuel consumption factors are applied to the data.

The mean fuel consumption rating versus maximum R.O.N. and (R + M)/2 Octane Number requirements for all vehicles including U.S. manufactured and imported vehicles were also calculated and are given in Table 3. From these data it may be observed that the mean fuel consumption ratings for all of the vehicles is relatively constant for all octane number groups. It may also be observed that the mean fuel consumption ratings for the imported vehicles are notably lower than the mean fuel consumption ratings for the U.S. vehicles.

Table 4 gives the maximum R.O.N. and (R + M)/2 Octane Number requirements versus mean accumulated mileage for the total sample of vehicles. From this it can be seen that the accumulated mileage was relatively constant for each of the octane number ranges represented.

5.0 DISCUSSION AND CONCLUSIONS

5.1 From an examination of the results, it is reasonable to assume that the 415 vehicles evaluated for the CRC for octane number requirement are typical of the new 1981 U.S. light duty vehicle population. However, it is noted:

- that the sample of vehicles had only accumulated an average of 10,601 miles, and no data are given in the CRC report on the octane number requirements for vehicles which have accumulated a greater number of average miles.

- that the CRC octane number requirement data were obtained using trained (knock) raters. Because of the rigorous testing protocol specified by the CRC it may be assumed that the ability of the general public to perceive engine knocks is probably less than that of the trained raters.

- actual fuel consumption could differ from the EPA and Transport Canada estimates because of driver and trip profile variations.

5.2 In light of Conclusion 5.1, the the octane number requirements to satisfy the 1981 U.S. light-duty vehicle population are as follows:

- for 90% satisfaction, an (R + M)/2 Octane Number of 91 is required, and
- for 50% satisfaction, an (R + M)/2 Octane Number of 86.5 is required.

5.3 If the vehicle population consumed fuel according to octane requirements, then the following percentages would be applied to the 1981 U.S. light-duty vehicle population:

- 90% of the fuel consumed would have an (R + M)/2 Octane Number of 91 or less, and
- 50% of the fuel consumed would have an (R + M)/2 Octane Number of 86.5 or less.

REFERENCES

1. "1981 CRC Octane Number Requirement Survey", CRC Report No. 525, Coordinating Research Council Inc., August, 1982.

2. "1981 Gas Mileage Guide, EPA Fuel Economy Estimates, First Edition, Federal (49 State)", U.S. Environmental Protection Agency, September, 1980.

3. "1981 Gas Mileage Guide, EPA Fuel Economy Estimates, First Edition, California", U.S. Environmental Protection Agency, September, 1980.

4. "1981 Fuel Consumption Guide, Edition 2", Transport Canada, Road Safety, February, 1981.

TABLE 1

MAXIMUM OCTANE NUMBER REQUIREMENTS VERSUS NUMBER OF VEHICLES AND FUEL CONSUMED (%)

Maximum Research Octane Number	Maximum $\frac{(R + M)}{2}$ [1] Octane Number	Number of Vehicles		Fuel Consumed %	
		U.S. Vehicles	Total [2] Vehicles	U.S. Vehicles	Total [2] Vehicles
L [3] → 80.9	L [4] → 78.9	6	7	1.34	1.54
81 → 81.9	79.0 → 79.8	0	1	0	.18
82 → 82.9	79.9 → 80.7	10	12	2.50	2.85
83 → 83.9	80.8 → 81.5	4	5	0.88	1.07
84 → 84.9	81.6 → 82.3	11	15	2.68	3.25
85 → 85.9	82.4 → 83.1	12	18	2.85	3.98
86 → 86.9	83.2 → 84.0	20	26	5.15	6.30
87 → 87.9	84.1 → 84.8	28	33	7.19	8.13
88 → 88.9	84.9 → 85.5	27	42	6.89	9.93
89 → 89.9	85.6 → 86.3	21	32	5.55	7.53
90 → 90.9	86.4 → 87.1	30	40	7.87	9.95
91 → 91.9	87.2 → 87.8	18	22	4.71	5.53
92 → 92.9	87.9 → 88.6	34	41	8.68	10.08
93 → 93.9	88.7 → 89.4	18	26	4.73	6.15
94 → 94.9	89.5 → 90.2	33	38	8.40	9.29
95 → 95.9	90.3 → 90.9	13	13	3.40	3.40
96 → 96.9	91.0 → 91.8	9	12	2.14	2.73
97 → 97.9	91.9 → 92.6	8	11	2.09	2.77
98 → 98.9	92.7 → 93.5	7	8	1.93	2.12
99 → H [5]	93.6 → H [6]	9	13	2.49	3.25
Total		318	415	81.50%	100%

(1) $\frac{(R + M)}{2}$ = Research Octane Number plus Motor Octane Number, divided by two or Road Octane Number

(2) Domestic (U.S.) and Imported Vehicles

(3) L : RON < 78

(4) L : $\frac{R + M}{2} < 76.15$

(5) H : RON > 100

(6) H : $\frac{(R + M)}{2} > 94.4$

TABLE 2

OCTANE NUMBER VERSUS CUMULATIVE PERCENT SATISFIED
AND CUMULATIVE PERCENT OF FUEL CONSUMED

Maximum Research Octane Number	Maximum $\frac{(R + M)}{2}$ Octane Number	Cumulative Percent of Vehicles Satisfied	Cumulative Percent Fuel Consumed
L (1)	L (2)	0.4	0.3
78	74.3	0.8	0.7
79	77.2	0.8	0.7
80	78.1	1.3	1.2
81	79.0	1.8	1.6
82	79.9	3.4	3.1
83	80.8	5.4	5.1
84	81.6	7.5	7.0
85	82.4	11.3	10.4
86	83.2	16.9	15.8
87	84.0	24.0	23.0
88	84.8	32.9	31.8
89	85.6	41.9	40.7
90	86.4	50.1	49.0
91	87.1	58.0	57.1
92	87.9	65.5	64.9
93	88.7	73.6	73.0
94	89.5	81.4	80.8
95	90.3	87.7	87.3
96	91.0	90.8	90.5
97	91.9	94.8	93.3
98	92.7	95.9	95.7
99	93.6	97.7	97.7
H (3)	H (4)	99.3	99.3

(1) L : RON < 78

(2) L : $\frac{(R + M)}{2}$ < 76.15

(3) H : RON > 100

(4) H : $\frac{(R + M)}{2}$ > 94.4

TABLE 3

MAXIMUM OCTANE NUMBER REQUIREMENTS VERSUS
MEAN FUEL CONSUMPTION VALUES

Maximum Research Octane Number	Maximum $\frac{(R + M)}{2}$ Octane Number	MEAN FUEL CONSUMPTION RATING, L/100 km		
		U.S. Vehicles	Imported Vehicles	U.S. & Imported Vehicles
L(1) → 80.9	L(2) → 78.9	9.9	8.7	9.7
81 → 81.9	79.0 → 79.8	-	7.8	7.8
82 → 82.9	79.9 → 80.7	11.1	7.7	10.5
83 → 83.9	80.8 → 81.5	9.7	8.7	9.5
84 → 84.9	81.6 → 82.3	10.8	6.2	9.6
85 → 85.9	82.4 → 83.1	10.5	8.3	9.8
86 → 86.9	83.2 → 84.0	11.4	8.5	10.7
87 → 87.9	84.1 → 84.8	11.4	8.3	10.9
88 → 88.9	84.9 → 85.5	11.3	9.0	10.5
89 → 89.9	85.6 → 86.3	11.7	8.0	10.4
90 → 90.9	86.4 → 87.1	11.6	9.2	11.0
91 → 91.9	87.2 → 87.8	11.6	9.1	11.1
92 → 92.9	87.9 → 88.6	11.3	8.9	10.9
93 → 93.9	88.7 → 89.4	11.6	7.9	10.5
94 → 94.9	89.5 → 90.2	11.3	7.9	10.8
95 → 95.9	90.3 → 90.9	11.6	-	11.6
96 → 96.9	91.0 → 91.8	10.6	8.6	10.1
97 → 97.9	91.9 → 92.6	11.6	9.9	11.1
98 → 98.9	92.7 → 93.5	12.3	8.1	11.7
99 → H(3)	93.6 → H(4)	12.2	8.4	11.1
Total		11.3	8.7	10.7

(1) L : RON < 78

(2) L : $\frac{(R + M)}{2} < 76.15$

(3) H : RON > 100

(4) H : $\frac{(R + M)}{2} > 94.4$

TABLE 4

MAXIMUM OCTANE NUMBER REQUIREMENTS VERSUS MEAN ACCUMULATED MILEAGE

Maximum Research Octane Number	Maximum $\frac{(R + M)}{2}$ Octane Number	Mean Mileage
$L^{(1)}$ → 80.9	$L^{(2)}$ → 78.9	9801
81 → 81.9	79.0 → 79.8	6900
82 → 82.9	79.9 → 80.7	10994
83 → 83.9	80.8 → 81.5	11104
84 → 84.9	81.6 → 82.3	8698
85 → 85.9	82.4 → 83.1	8943
86 → 86.9	83.2 → 84.0	9839
87 → 87.9	84.1 → 84.8	10695
88 → 88.9	84.9 → 85.5	10910
89 → 89.9	85.6 → 86.3	11584
90 → 90.9	86.4 → 87.1	10490
91 → 91.9	87.2 → 87.8	11341
92 → 92.9	87.9 → 88.6	10773
93 → 93.9	88.7 → 89.4	11304
94 → 94.9	89.5 → 90.2	10712
95 → 95.9	90.3 → 90.9	10436
96 → 96.9	91.0 → 91.8	11873
97 → 97.9	91.9 → 92.6	9243
98 → 98.9	92.7 → 93.5	8545
99 → $H^{(3)}$	93.6 → $H^{(4)}$	11746
Mean		10611

(1) L : RON < 78

(2) L : $\frac{(R + M)}{2}$ < 76.15

(3) H : RON > 100

(4) H : $\frac{(R + M)}{2}$ > 94.4

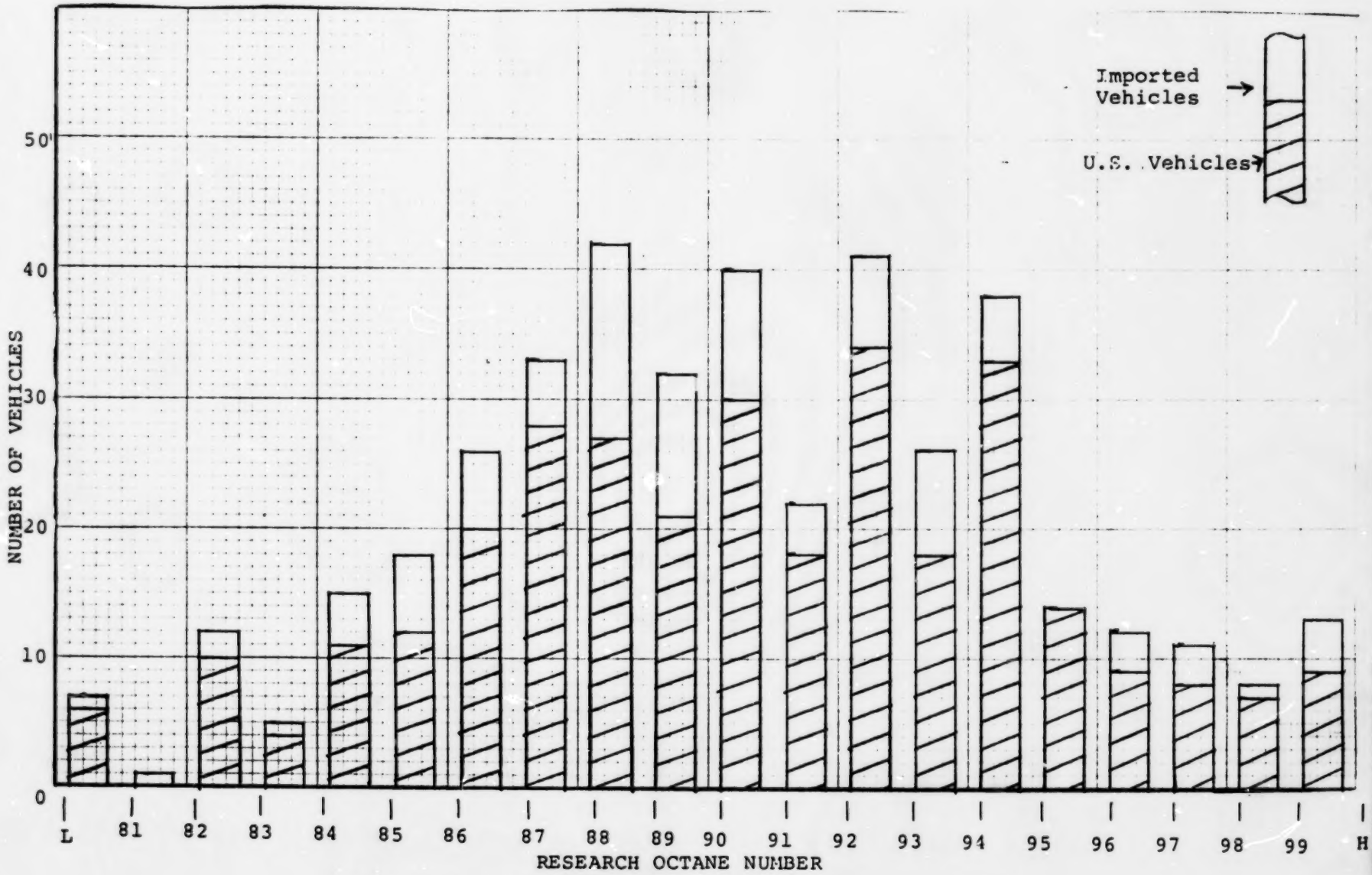

FIGURE 1. MAXIMUM RESEARCH OCTANE NUMBER REQUIREMENT VERSUS NUMBER OF VEHICLES

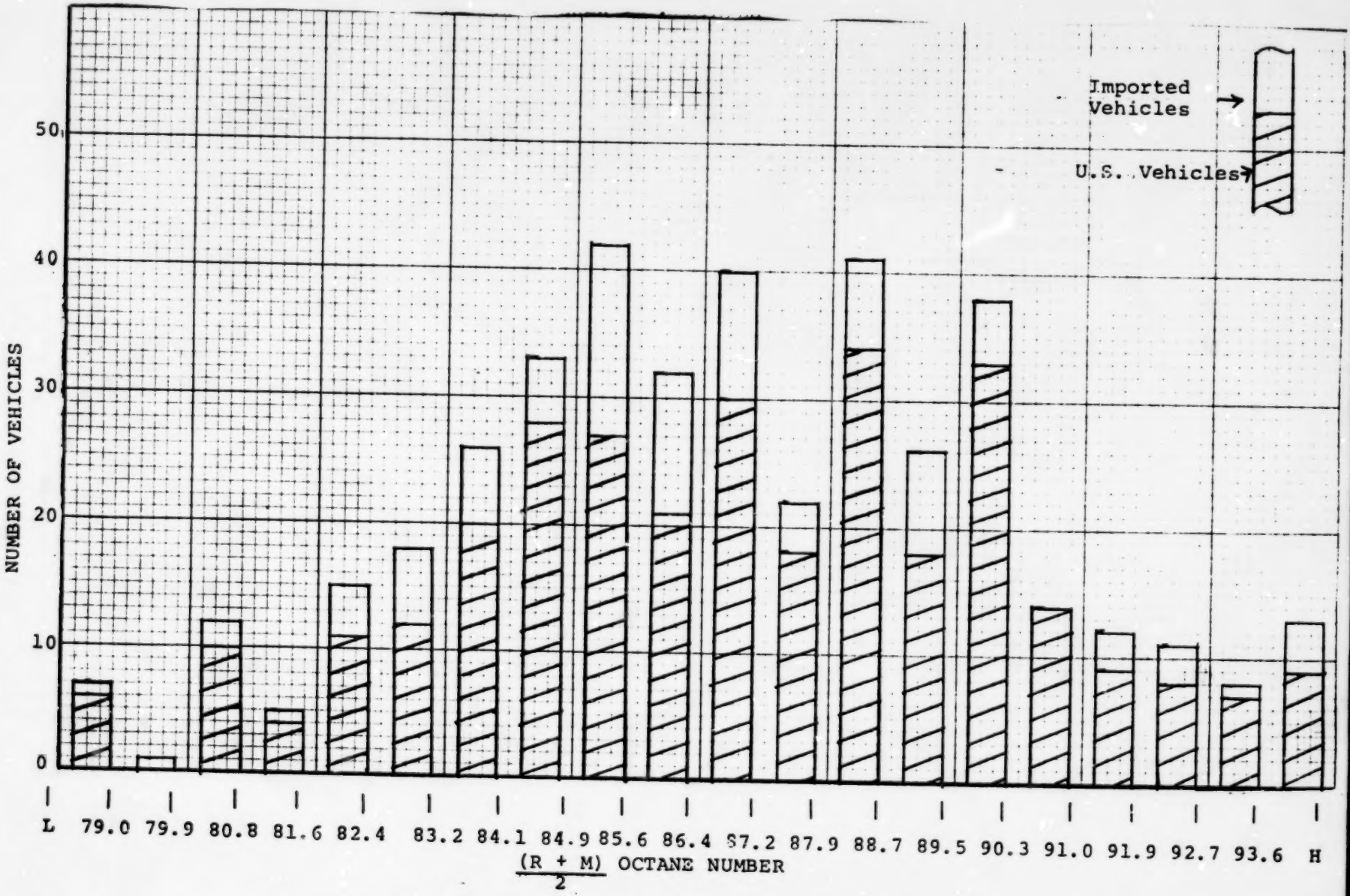

FIGURE 2. MAXIMUM (R + M) OCTANE NUMBER REQUIREMENT VERSUS NUMBER OF VEHICLES

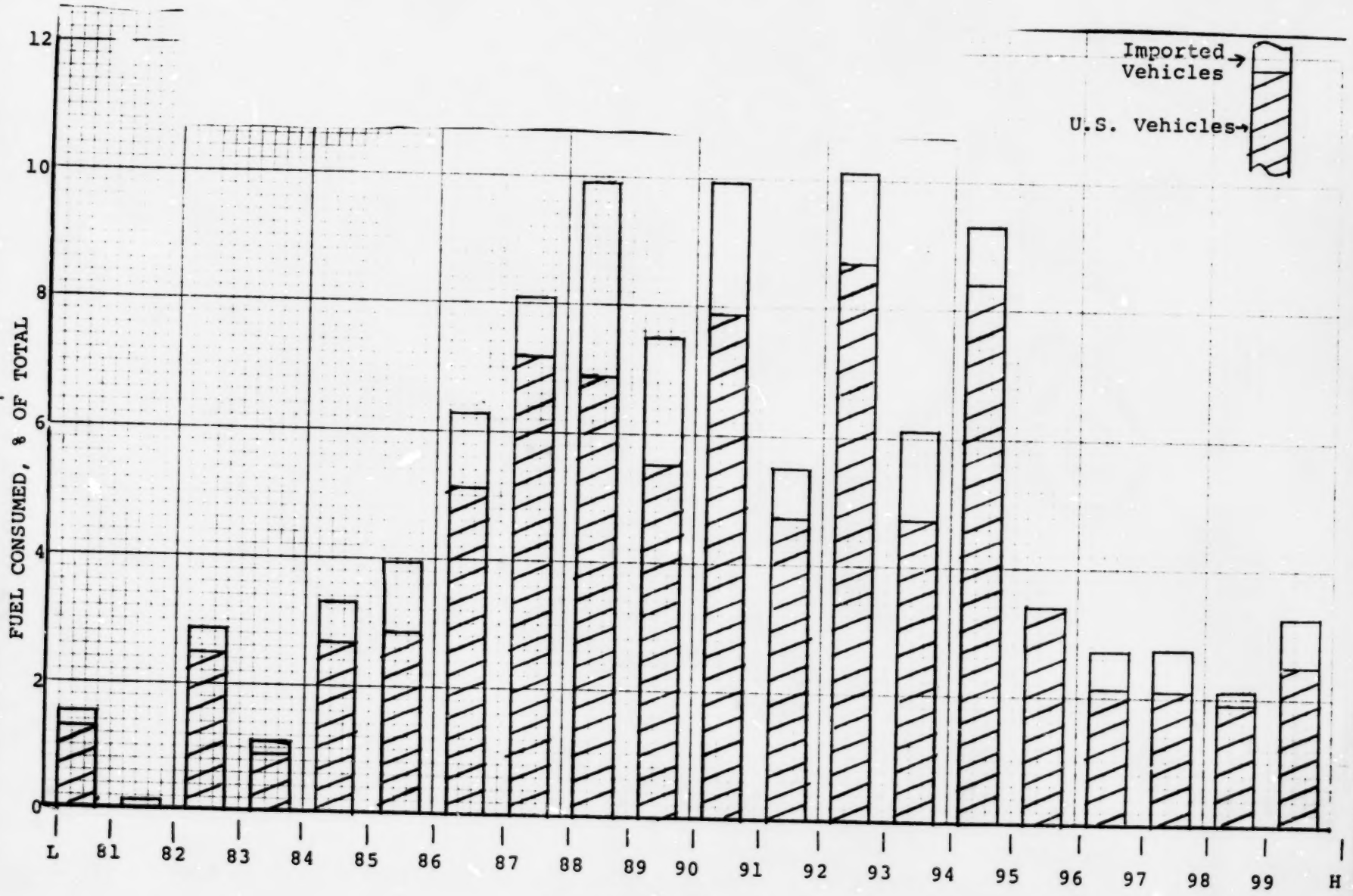

FIGURE 3. MAXIMUM RESEARCH OCTANE NUMBER REQUIREMENT VERSUS FUEL CONSUMED (% OF TOTAL)

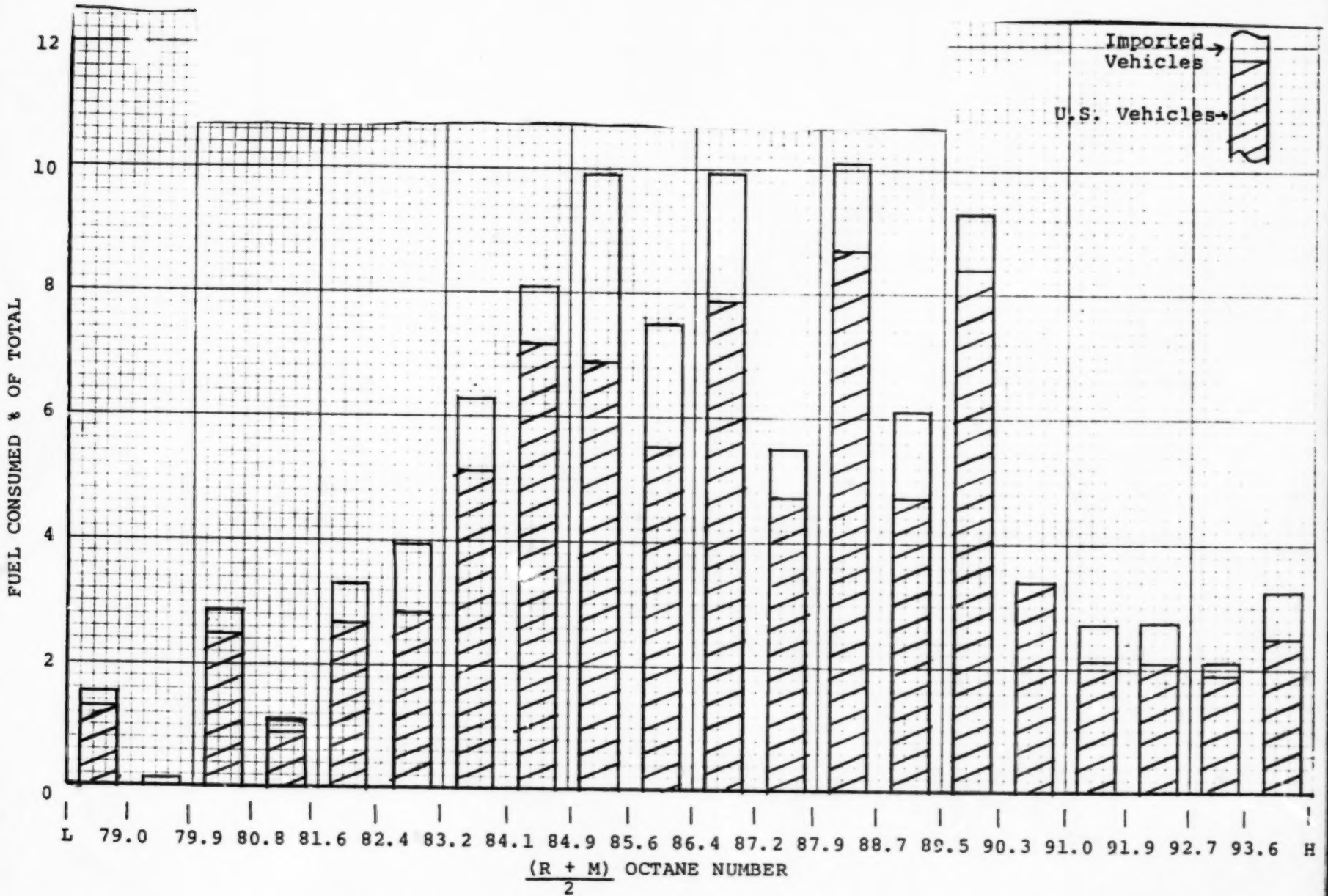

FIGURE 4. MAXIMUM $\frac{(R + M)}{2}$ OCTANE NUMBER REQUIREMENT VERSUS FUEL CONSUMED (% OF TOTAL)

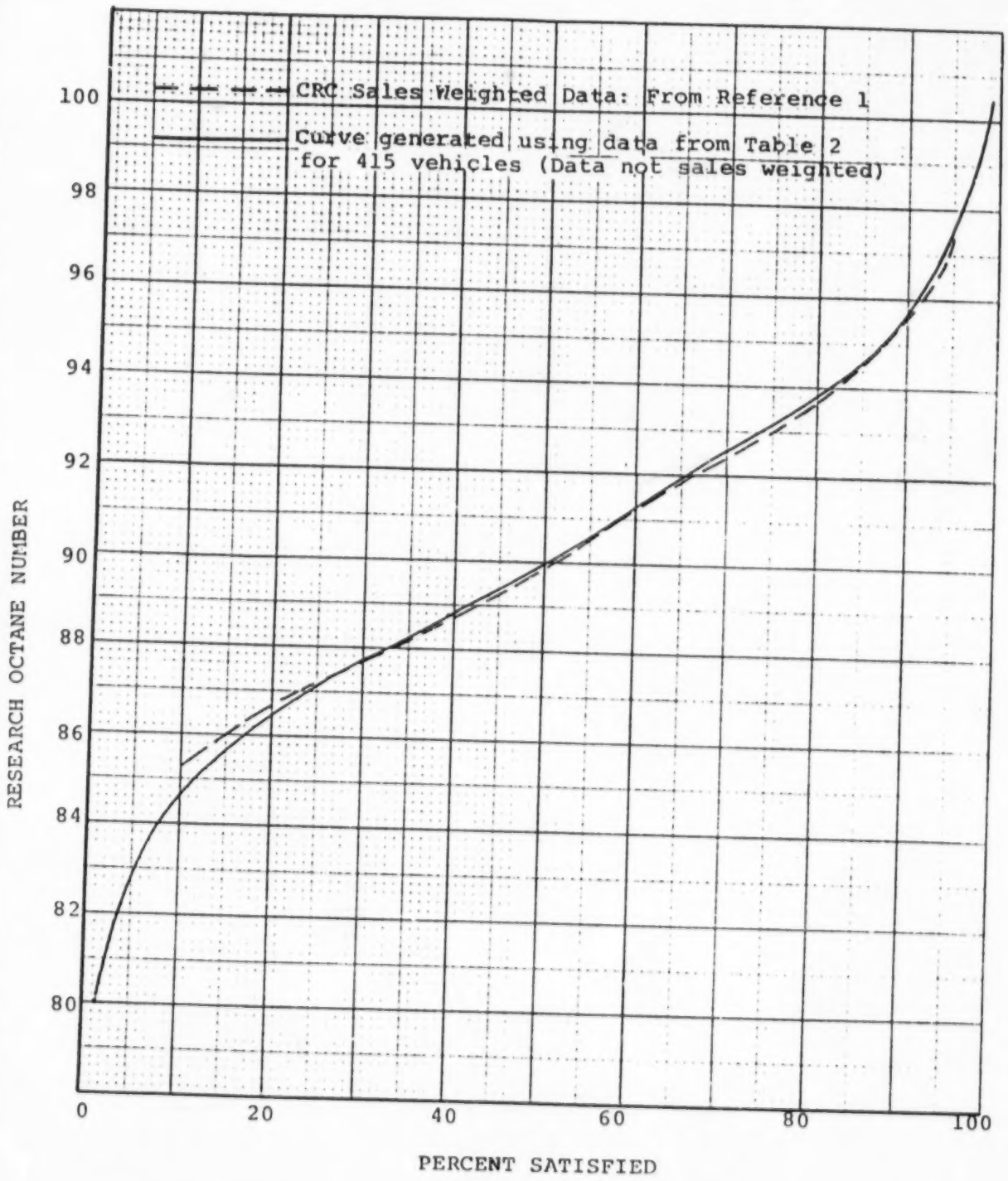

FIGURE 5. MAXIMUM R.O.N. REQUIREMENTS FOR 1981 U.S. AND IMPORTED VEHICLES

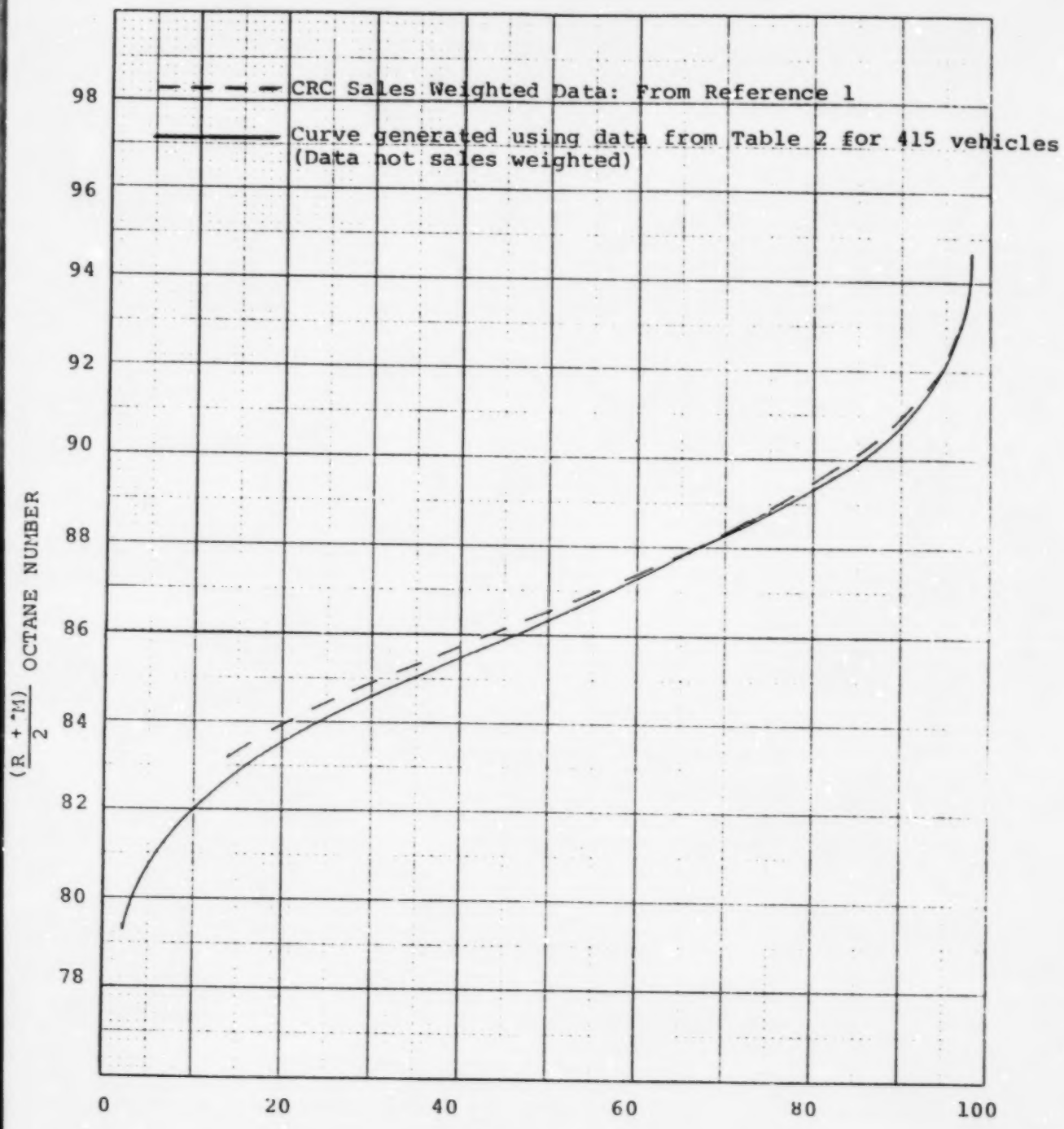

FIGURE 6. MAXIMUM $\frac{(R + M)}{2}$ OCTANE NUMBER REQUIREMENTS FOR 1982 U.S. AND IMPORTED VEHICLES

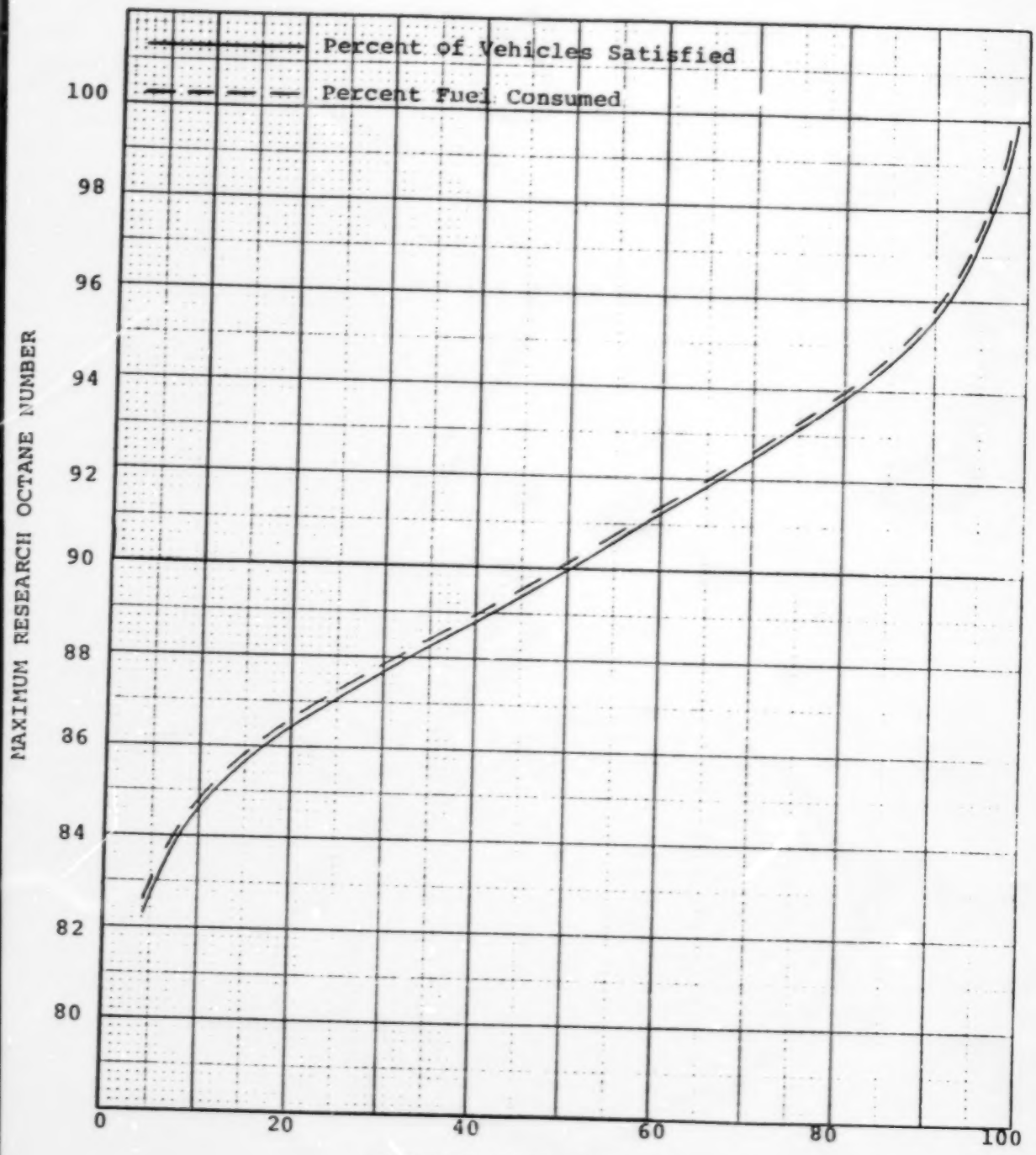

FIGURE 7. MAXIMUM R.O.N. REQUIREMENT FOR 415 1981 U.S. AND IMPORTED VEHICLES

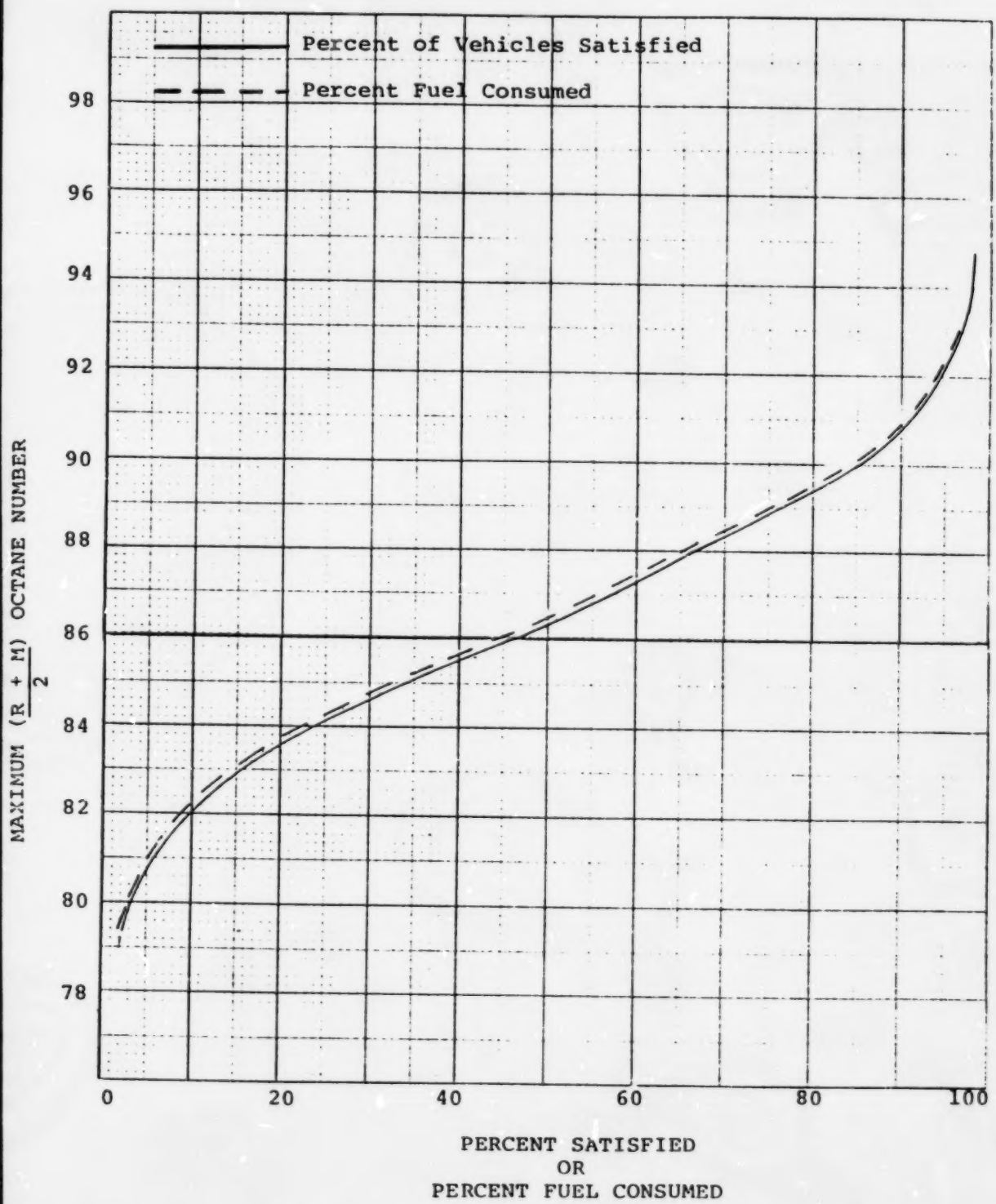

FIGURE 8. MAXIMUM $\frac{(R + M)}{2}$ OCTANE NUMBER REQUIREMENT FOR 415 1981 U.S. AND IMPORTED VEHICLES

POOR

QUALITY

ORIGINAL